REPORT 6

SWEEP

SOIL AND WATER
ENVIRONMENTAL
ENHANCEMENT PROGRAM

PAMPA

PROGRAMME D'AMÉLIORATION
DU MILIEU PÉDOLOGIQUE
ET AQUATIQUE

Canada

Ontario

SWEEP

is a $30 million federal-provincial agreement, announced May 8, 1986, designed to improve soil and water quality in southwestern Ontario over the next five years.

PURPOSES

There are two interrelated purposes to the program; first, to reduce phosphorus loadings in the Lake Erie basin from cropland run-off; and second, to improve the productivity of southwestern Ontario agriculture by reducing or arresting soil erosion that contributes to water pollution.

BACKGROUND

The Canada-U.S. Great Lakes Water Quality Agreement called for phosphorus reductions in the Lake Erie basin of 2000 tonnes per year. SWEEP is part of the Canadian agreement, calling for reductions of 300 tonnes per year — 200 from croplands and 100 from industrial and municipal sources.

PAMPA

est une entente fédérale-provinciale de 30 millions de dollars, annoncée le 8 mai 1986, et destinée à améliorer la qualité du sol et de l'eau dans le Sud-ouest de l'Ontario.

SES BUTS

Les deux buts de PAMPA sont: en premier lieu de réduire de 200 tonnes par an d'ici 1990 le déversement dans le lac Erie de phosphore provenant des terres agricoles, et de maintenir ou d'accroître la productivité agricole du Sud-ouest de l'Ontario, en réduisant ou en empêchant l'érosion et la dégradation du sol.

SES GRANDES LIGNES

L'entente entre le Canada et les États-Unis sur la qualité de l'eau des Grands Lacs prévoyait de réduire de 2 000 tonnes par an la pollution due au phosphore dans le bassin du lac Erie. PAMPA fait partie de cette entente qui réduira cette pollution de 300 tonnes par an — 200 tonnes provenant des terres agricoles et 100 tonnes provenant de sources industrielles et municipales.

100-05201/

A SURVEY OF CROP RESIDUE IN SOUTHWESTERN ONTARIO 1987

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This report has been prepared by the authors for the Management Committee of the Soil and Water Environmental Enhancement Program (SWEEP).

The views and interpretations contained herein are based on the data collected and reported by the authors and does not necessarily reflect the views of the SWEEP Management Committee, Environment Canada, Ontario Ministry of Agriculture and Food, Ministry of the Environment and Agriculture Canada.

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1.0 EXECUTIVE SUMMARY

This report represents the results of a study of crop residue conducted by a combined windshield/on-site survey of over 10,000 fields in Southwestern Ontario in the spring of 1987. The purpose of the survey was to provide a detailed data base for the Soil and Water Environmental Enhancement Program (SWEEP). SWEEP is a 5-year program aimed at reducing phosphorus loadings from cropland run-off and to improve or maintain the productivity of agriculture in the Lake Erie Basin. The survey gathered baseline data for percent residue cover of the soil surface for various combinations of crops and tillage systems.

Conservation tillage practices increase residue cover and enhance erosion control. This data, along with that collected in the "Cropping, Tillage and Land Management Practices" report of March, 1987 will allow estimation of relative soil loss from fields. It will also serve as a benchmark against which the effect of implementing soil and water management practices can be evaluated at the conclusion of the SWEEP Agreement.

The survey was conducted by driving predetermined random routes twice through the counties of the SWEEP study area, with stops approximately every 0.8 km to record cropland information. At each site information was gathered on present crop, residue levels of the previous crop, and tillage type.

An attempt was made to include a representative sub-sample of interview survey sites visited in the "Cropping, Tillage and Land Management Practices" study (Coleman & Roberts, March 1987), in order to allow comparison of crop residue data with detailed cropping and tillage information.

An analysis of the data reveals that 16% of fields in Southwestern Ontario have 20% or more residue cover, while just 10% of the fields surveyed had 30% residue cover.

Residue levels were compiled on a county and regional municipality basis, by tillage type previous crops and cropping sequence.

Study results showed that conventional tillage occurred most commonly (72.8%), while 18.6% of fields were not tilled, 8.0% were reduced tilled and 0.5% were ridge tilled. Over 95% of conventionally tilled fields occurred in the 0-15% residue category, while 3% of conventionally tilled fields occurred in the 75-100% category. For reduced tillage, most fields were in the 15-30% residue category at 40.6%, with a similar response (40.0%) in the 30-45% residue category.

The higher residue categories are dominated by fields in the not-tilled category. Most of this category was made up of forage and hay residue. These are densely growing crops which tend to provide a high degree of surface cover.

County results showing the distribution of crops planted indicate that corn (26.3%) was predominant. Hay or forage constituted 20.9%, while spring and fall grain made up 11.9% and 12.5% respectively.

To assess the representativeness of the results, the information was compared to the distribution of crops by county found in the report by Coleman and Roberts, 1987. A good deal of similarity was seen among percentage occurrence of the various crops between the two surveys.

Reliability of the crop residue estimate was judged by a cross-tabulation of actual measured residue cover in percent with estimated residue cover. For all residue cover categories, it was found that one can be over 96% confident that when a residue cover class was estimated, the value was in its proper class.

Residue levels of previous crops that were not identifiable (fallow), occurred 3.8% of the time in the Before Secondary Tillage (BST) phase, but their occurrence increased to 12% in the After Secondary Tillage (AST) phase of the study. Results showed that during the AST phase, higher proportions of fields occurred in the 0-15% residue cover category, while most decreases occurred in the 45-75% and 75-100% residue categories.

With the exception of small grains, the proportion of fields in the 0-15% residue category increased markedly during the AST phase, for most crops.

For example, the proportion of fields in corn having just 0-15% residue cover increased from 70.4% during the BST phase to 83.3% during the AST phase. By comparison, the number of corn fields having residue in the higher residue categories fell by approximately 13 percentage points.

The proportion of fields in beans having 0-15% residue increased from 61.4% during the BST phase to 95.6% during the AST phase. For beans, the higher residue categories lost a total of approximately 34 percentage points. With the exception of forages, corresponding losses in residue occurred for the remaining crops.

During the BST phase, 54% of forage fields occurred in the 0 - 15% residue category. These were fields which had been plowed down in preparation for planting another crop.

Hay which remained during the AST portion of the study was being kept an additional year. As a consequence, 83.5% of the entries in the 75-100% residue category are a result of forages being maintained from year to year.

Cropping sequences were one of the more interesting pieces of information available from the survey. For example, where the present crop was corn, 63.4% of those fields had previously been corn, 16.6% of present corn crops had previously been small grains while 11.1% of fields had previously been seeded to beans. Four percent of present corn fields had insufficient residue to determine what the previous crop had been.

An analysis of crop residue for a previous crop-present crop combination can show the probability of having a certain level of residue through many types of cropping sequences. As an illustration, the mean value of residue cover resulting from a corn - corn - grain - hay - hay rotation is provided. In the first year when corn follows a previous crop of hay, a 10% level of residue was found on average. In the second year when corn follows corn, one would expect to find 12% residue cover. In the third year of the rotation, when spring grain follows corn, an average residue cover of 9% would likely be found. When hay follows spring grain in the fourth year, a crop residue cover of 33% would be anticipated. In the final year of the rotation when hay follows hay an average residue cover of 73% would result. Over this rotation, the average value of crop residue was 27%.

Average residue cover levels for any other crop sequence can be derived with the data found in this report. Results showed that incorporating a forage/hay into a rotation increased crop residue cover substantially.

The survey was designed to collect information about crop residues before secondary tillage (after-wintering) and after secondary tillage (after-planting). The before secondary tillage information proved to be useful only in a limited fashion. The only crops in the before secondary tillage category during the spring are untilled crop stubble and primary tilled fields. Forage/hay and fall planted grains are crops which have already received secondary tillage. The main value of the before secondary tillage portion of the survey is to allow estimation of the over-winter protection afforded by stubble, forage or fall grain.

This report contains only the highlights of the extensive data collected through this survey. This data will enable additional analysis and comparisons to be made and will be used to evaluate the effects of conservation practices in the SWEEP program.

2.0 BACKGROUND

2.1 Save Our Soil

Ontario soils are among the most productive in Canada. However, a report to the Working Group on Soil and Water Conservation and Development, 1986 and one by G.J. Wall and G.A. Driver, 1982 have identified the following 4 major processes affecting sustained productivity and soil erosion:

1. A progressive loss of soil organic matter.
2. Soil structure deterioration and soil compaction.
3. Topsoil erosion.
4. Reduced available water returned to the soil.

Soil erosion and reduced productivity result in at least 6 economic losses:

1. Reduced yield
2. Lost nutrients and pesticides
3. Soil degradation
4. Increased energy costs
5. Sedimentation of drainage ditches & stream channels
6. Dissected fields and reduced operational efficiency

These damages are recognizable but difficult to cost. For factors that have been quantified, "annual cropland soil erosion costs in Ontario are estimated to be $68 million from yield reduction and nutrient/pesticide losses. An additional $6 million is estimated as the annual cost of maintaining surface and subsurface drainage systems." (Ontario Institute of Agrologists, 1983).

Soil degradation, a result of a loss of tilth and water holding ability and declining soil organic matter. Loss of organic matter shows itself as light coloured knolls, surface crusting, weak structure and poor aggregation. The unrelenting loss of soil organic matter can manifest itself as gully or sheet erosion, and can contribute to the muddied appearance of streams. These actions transport phosphorus into larger bodies of water such as the Great Lakes. A well-aggregated soil resists the erosion of soil particles by wind and water. Crop residue levels exceeding 30% cover add organic matter and decreases the velocity of overland runoff.

Susceptibility to erosion is greatest after ploughing, seedbed preparation and seedling establishment. In Ontario, there can be a period of 6-8 months when little or no vegetation covers the soil.

There are several ways to reduce/control soil erosion and enhance water quality, such as:

1. Minimize tillage passes over a field to leave residue on the soil surface after planting,

2. Eliminate summer fallow, and grow cover crops and green manure crops wherever possible,

3. Maintain crop rotations that enhance soil structure and allow plowdown, strip cropping and field borders,

4. Plough and plant across the slope or on the contour,

5. Incorporate manure according to the Agricultural Code of Practice,

6. Apply fertilizer by recommendation of soil test,

7. Provide for either living windbreaks and shelterbelts or engineered surface water management systems.

This study addresses percentage residue cover and its relationship to present and previous crops and tillage type. Ketcheson, Vyn and Daynard 1983 maintained that crop residues remaining after the harvest of crops are the single most effective and practical means to control soil erosion.

The decomposition of crop residue material in soil is essential to the maintenance of good soil structure and tilth. The regular and adequate addition of crop residues is necessary to support the process of decomposition.

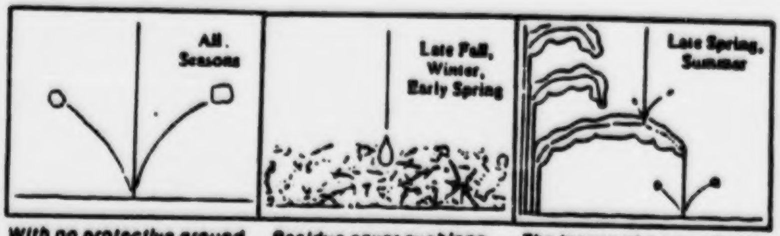
Ketcheson and Vyn, 1983 stated that approximately one tonne of crop residue (dry basis) is produced for every tonne of grain produced. A corn crop produces about 6 tonnes of dry matter per hectare as stover. Cereal grain crops produce about 3 tonnes of dry matter per hectare as straw. If crop residues are mostly incorporated into the soil through excessive tillage or diverted from fields, soil organic matter and productivity will ultimately decline.

2.2 Residue Management

The management of crop residues is important in controlling the process of accelerating organic matter loss, and hence soil erosion. This type of management means less tillage, greater surface residue, modifications in seeding and weed control methods, as well as savings in time and fuel. To plant into high levels of residue on the soil, the tillage implement must move residue from the planting row. Planting machines with tilling coulters and disc openers can help prepare the seedbed and allow for close seed-soil contact necessary for moisture transfer and germination. However, it is when residue management practices are not followed that soil is exposed to the impact of falling rain drops. Figure 1 shows that with no protective ground cover, rain drops can splash soil particles up to three feet.

Residue cover cushions the fall of rain drops and hinders splash erosion. The leaves of crops also absorb falling rain drops and reduce the splashing action of soil and water.

Figure 1 The Action of Raindrops on Soil



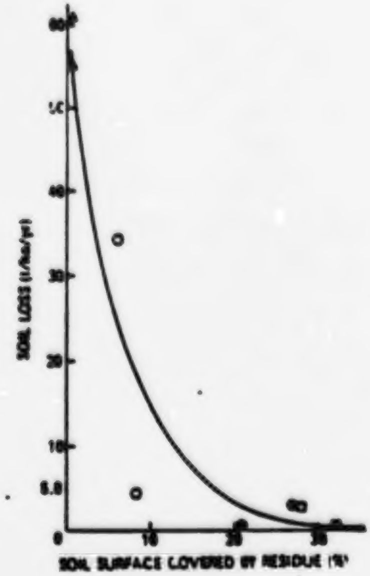
Graphics courtesy of Illinois Research, University of Illinois

Source: Conservation Tillage Handbook U.S.D.A. Soil Conservation Service, La Salle County Soil and Water Conservation District

After a crop is established, its canopy helps shelter the soil surface from the impact of rain drops. If erosion is to be significantly reduced, a surface cover must be provided on the soil during periods when bare soil is exposed to natural forces. For example, this cover can consist of clover plowdown or secondary crops underseeded with the principal crop or simply the proper management of crop residues. It may be necessary to take additional measures by installing properly designed erosion control structures. Funding for these structures is available through the Ministry of Agriculture and Food's Ontario Soil

Conservation and Environmental Assistance Program (OSCEPAP II) as well as the Land Stewardship Program.

Figure 2 The Relationship Between Soil Loss and Crop Residue



Source: Ontario Ministry of Agriculture and Food Factsheet: Tillage Practices for Residue Management and Erosion Control, Agdex 100/516 Order Number 83-087, November, 1983.

Figure 2 shows that residue gives erosion control benefits. For example, the coverage of as little as 5% of the soil surface by residues results in soil losses of over 20 tonnes/ha/year. With 20 percent of the soil surface covered, the soil loss is reduced to less than 5 tonnes/ha/year. An increase of crop residue cover by a factor of four times reduces soil losses by six times the amount.

2.3 Tillage Practices

Conservation (reduced) tillage should leave 30% of the previous crop's residue near or on the surface and between the rows after planting. This level of residue may be difficult to achieve in a conservation system when the previous crop was soybeans. Moldboard ploughing, however, disturbs the total soil surface by cutting, inverting and shattering the soil. Tillage with the moldboard plough and cultivator is known to leave between 0-15% crop residue after planting (Ketcheson and Vyn, 1983). A summary of the definitions of Tillage Systems is found in Appendix B. Moldboard ploughing has been found on 74% of farm fields in Southwestern Ontario (Coleman and Roberts, 1987).

2.4 Residue Cover Levels

Residue cover levels of 30% or more offer good soil erosion protection. Estimating the residue cover in fields is important in identifying soil erosion problems and determining the amount of residue needed to effectively control erosion. This assessment of residue levels will allow evaluation of the future progress of SWEEP and the necessary adjustment and operation of equipment to achieve appropriate levels of residue cover to reduce soil erosion. A reliable way to determine the amount of surface residue is to use the knotted rope method.

3.0 INTRODUCTION

3.1 Study Rationale

Soil erosion, sediment delivery to watercourses, and potential phosphorus loadings from land use activities were documented in reports by the Pollution from Land Use Activities Reference Group (PLUARG) of the International Joint Commission (IJC). The Canada - U.S. Great Lakes Water Quality Agreement calls for an annual phosphorus reduction in the Lake Erie Basin of 2000 tonnes by 1990. The Canada-Ontario Agreement on Great Lakes Water Quality calls for a reduction of 300 tonnes. To achieve this, a reduction target of 200 tonnes from agricultural cropland sources and 100 tonnes from industrial and municipal sources has been set as the goal to be met by the year 1990.

Action has been taken to address the above concerns and practices. In May 1986, a 5-year, $30 million agreement between the provincial and federal governments established the Soil and Water Environmental Enhancement Program (SWEEP). The two interrelated purposes of this program are:

1) To reduce phosphorus loadings by 200 per year in the Lake Erie Basin from cropland run-off;

2) To improve soil productivity by reducing or arresting soil erosion.

Under SWEEP, Agriculture Canada is responsible for research including pilot watershed studies, technology evaluation and development and socio-economic effects of conservation measures on individual farms. The Ministry of the Environment and Environment Canada are providing supportive monitoring services for SWEEP. The Ontario Ministry of Agriculture and Food provides technical assistance, on-farm demonstrations and grants to financially

assist farmers in the SWEEP area. This program contains a public information component supported by all participating agencies.

SWEEP will monitor progress during the latter part of the Agreement to establish changes in the use and location of the above practices. With this baseline established, subsequent studies will identify the adoption rate of conservation practices. With additional information, an estimate can be made to determine the phosphorus reduction in the Lake Erie Basin.

For SWEEP to be able to determine the amount of conservation practices adopted in the Lake Erie Basin, two surveys of the state of cropping, tillage, planting, land management practices, and fertilizer use must be conducted. The Soil and Water Management Branch, OMAF and the Lands Directorate, Environment Canada conducted the first survey during the summer of 1986. The anticipated second survey will enable comparisons and evaluation.

The Report of the Working Group on the Measurement of Land Management and Cropping Practices, May 1986, recommended a separate study of crop residue cover.

Some Ontario data does exist for the quantity of crop residue using various tillage systems. However, most of these data are measures of corn residue. Little data is available for such crops as soybeans and cereals. It is also recognized that the Tillage 2000 project will obtain residue cover data from approximately 30 sites across the Province in the next three years (Report to the Working Group on Soil and Water Conservation and Development, July 1986).

This crop residue study required an accurate, fast and efficient method to determine levels of residue throughout the SWEEP study area. The chosen method, a residue cover transect survey, based upon a study jointly conducted by the Ohio Department of Natural Resources and the Soil Conservation Service of Ohio, tracked conservation tillage adoption and crop residue levels.

This study differs from the Ohio study in that data on crop residue was collected before and after the time of secondary tillage during the spring. The random, point-sampling method used in the study, has measured reliability and confidence levels and is objective fast and efficient.

Non-point source pollution from cropland caused by soil erosion and pesticide loss can be effectively reduced by conservation tillage. It is currently the most common practice promoted by soil conservation programs in the United States (Kush and Crawford, 1987). Adoption of soil conservation practices including tillage practices was conducted by personal interview survey (Coleman and Roberts, 1987).

Examination of the 1987 study's general findings such as the use of: crop rotations; the modified moldboard and chisel plough; shallow ploughing depth; crop rotations to reduce erosion; ploughing and planting with little consideration for the slope, application of phosphorus based without a soil test and little reforestation indicate that the largest part of the farm community is not yet using conservation practices.

Field verification at the county level is necessary to obtain reliable benchmarks against which the effect of

implementing soil and water management programs can be evaluated at the conclusion of the SWEEP agreement.

3.2 Definition of the Study Area

The SWEEP Land Management and Cropping Practices Working Group defined the SWEEP study area to include the counties of Essex, Kent, Lambton, Huron, Perth, Middlesex, Elgin, Oxford, Brant, and the Regional Municipalities of Waterloo and Haldimand-Norfolk. All of the townships of Wellington were included except Minto, Arthur, West Luther and Eramosa. In Hamilton-Wentworth, the townships of Glanbrook and Ancaster were included. The extent of the SWEEP study area is shown in Figure 3. This survey attempted to cover as much as possible of the arable land in the study area. Table 3 lists the townships not covered by this residue cover transect survey.

3.3 Goals and Objectives

The goal of this study was to obtain Ontario baseline data for percent residue cover of the soil surface for various combinations of crop which impact on phosphorus delivery in the Lake Erie watershed. This data along with that collected in the Cropping, Tillage and Land Management Practices survey March, 1987, will serve as a benchmark against which the adoption of soil and water conservation programs can be evaluated at the conclusion of the SWEEP agreement.

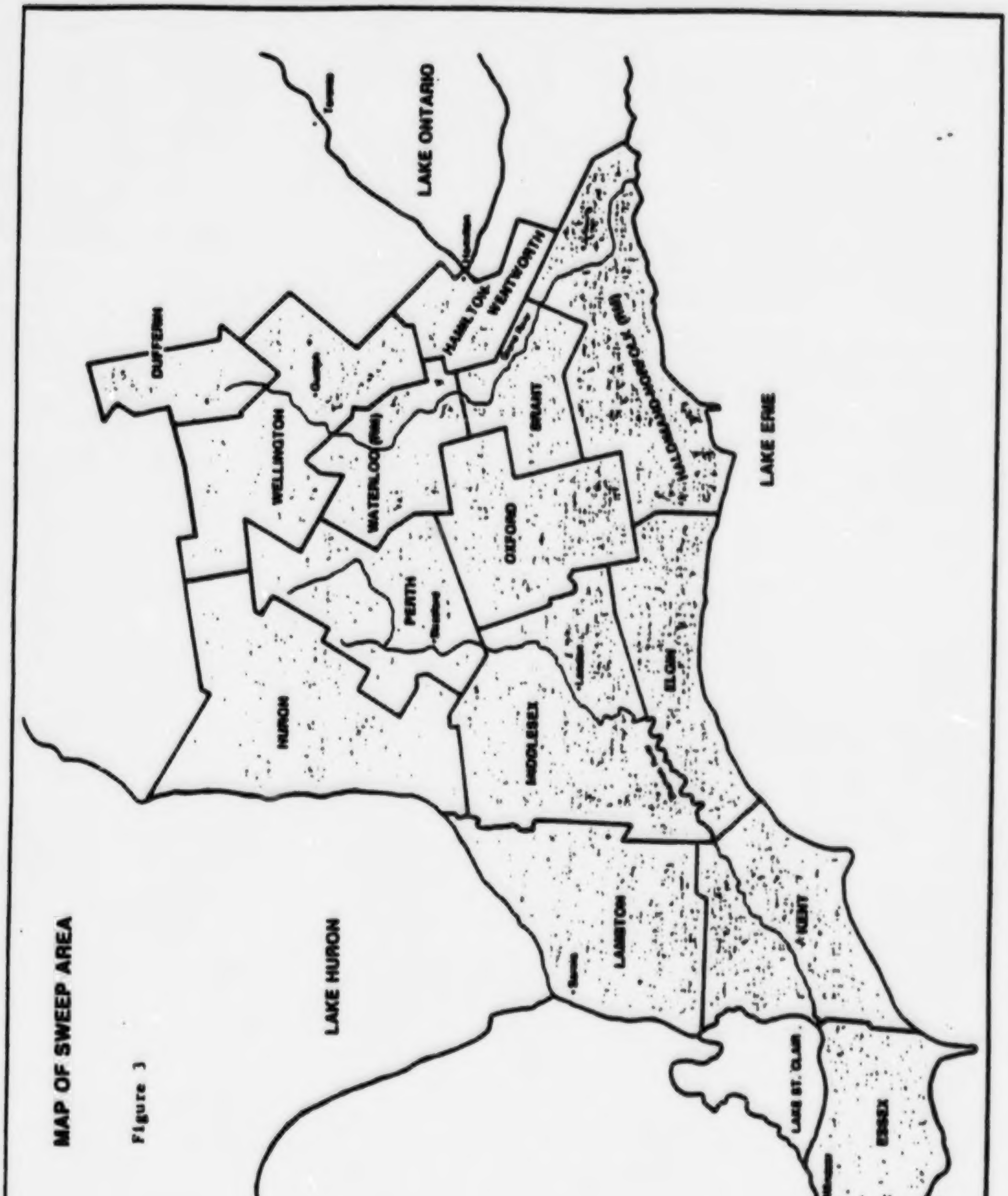
The following objectives derived from this goal were to:

1) Estimate percentage previous crop residue for crops in the SWEEP study area;

2) Record tillage types associated with these crops;

3) Measure actual residue found in fields at predetermined sample points;

4) Correlate data with information from the tillage and cropping practices survey, March 1987.



MAP OF SWEEP AREA

Figure 3

4.0 METHODOLOGY

4.1 Introduction

The following section will deal with sampling design including consideration of sub-sampling of the 1,115 sites used in the 1986 study of Cropping, Tillage and Land Management Practices (Coleman and Roberts, 1987); stratification into before secondary tillage (after-wintering) and after secondary tillage (after-planting); preparations for fieldwork; sample size and confidence; and limitations to the study.

The reader should be aware that secondary tillage is normally viewed as a process, and that "after secondary tillage" would imply tilling had been done. As used in this report "after secondary tillage" refers to the time of data collection. Thus fields may remain untilled at that time.

4.2 Sample Size and Confidence

The number of fields required for the roadside residue cover transect survey was determined by degree of confidence, confidence limits, number of categories measured and prior knowledge of population distribution.

To draw a statistically reliable sample, Kush and Crawford's method using the multinomial distribution was adapted (Kush and Crawford, 1987).

The multinomial distribution (Figure 4) estimates the probability distribution of the proportions of each categories occurrence when more than two categories are considered. Using the multinomial distribution was appropriate because this survey was concerned with estimating four tillage categories (conventional, reduced,

not tilled and ridge till) and five residue cover ranges in percent (0-15, 15-30, 30-45, 45-75, 75-100).

Several assumptions can be made when using this equation. Kush and Crawford 1986, citing Krieger, based their assumptions and calculations on his tested population sample. They therefore knew the least number of samples needed to maintain comparable accuracy.

Ninety percent was set as the necessary level of confidence for the sampled data. Then, using the formula in Figure 4, P = 90, k = 5 (tillage categories), =.05, then alpha becomes (1 -0.90) = 0.10. Furthermore, Kush and Crawford assumed that 70% is a better approximation of the true distribution than the <u>a priori</u> p value of 50% for all categories. Using this assumption and solving the multinomial equation for K=5 residue cover categories and the other parameters gives a sample size of 456 samples (Figure 4). Table 6 shows various confidence levels determined by changing the variables of the equation.

Table 1 Use of the Multinomial Equation to Determine Size for Various Confidence Levels

P	(1-P)	s	p	k	= n
0.95	0.05	0.05	0.5	4	625
0.95	0.05	0.05	0.5		633
0.95	0.05	0.05	0.7	4	525
0.95	0.05	0.05	0.7	5	557
0.95	0.05	0.10	0.7	4	131
0.95	0.05	0.10	0.7	5	140
0.90	0.10	0.05	0.7	4	421
0.90	0.10	0.05	0.7	5	456
0.90	0.10	0.10	0.7	4	105
0.90	0.10	0.10	0.7	5	114

Source: Kush and Crawford 1986, Ohio Soil and Water Conservation District's Tillage and Residue Cover Transect Survey, Eleven Northwest Ohio Counties.

It was also known from prior experience that 74% of fields in the SWEEP study area were moldboard ploughed (Coleman and Roberts 1987).

Figure 4 Multinomial Distribution Equation Used To Determine The Survey Sample Size

Let $n = X^2_{1,1-\alpha/k} P_j(1 - P_j)/\delta J^2$,

where

n = sample size

$X^2_{1,1-\ /k}$ = Chi-square value from a Chi-square table with one degree of freedom and the value of $1 - \alpha/k$ substituted for 1 - in the table.

α = 1 - P

P = confidence level or degree of confidence that we have in the proportions arrived at for each category k = number of categories

p = a priori estimate (estimate from prior knowledge given of the proportions of the category). The proportion closest to 50 percent since n will be largest for p = 50%.

δ = confidence limits of the proportions, ie. the allowable error in the proportions (+5%, 10%, etc.)

Solving the Equation for four residue categories at the 95% confidence level, we have :

P = 0.95
k = 4 residue cover categories
p = .70
δ = 1 - 0.95 (.05)

$X^2_{1,1-\alpha/k}$ becomes $X^2_{1,0.99}$, and from a Chi-square table

$$X^2_{1,0.99} = 6.63$$

Solving for n,

$$n = 6.63 \times .70\ (1 - .70)/.05^2$$

$$= 557 \text{ fields}$$

Source: Kush and Crawford, 1987

For five residue categories, using the 90% confidence level, the number of fields required is four hundred and fifty six.

Kush and Crawford maintain that, depending upon survey results, more or less samples will be needed for future surveys to achieve the same reliability. They state that the farther below the assumed value of 70% that the true p value is, the more fields must be sampled. Conversely, the farther above the assumed p value of 70% the true p value is, the less fields will need to be sampled.

In the Kush and Crawford 1986 survey, the 456 cropland points (fields) to sample were to be recorded by one pass over a driving route. In the present study, residue levels were recorded before and after secondary tillage. During the course of the study, 456 sample points or greater were collected in 11 of the 12 counties in the survey.

From this and work by Kush and Crawford 1986 and many others it was assumed that each tillage practice would give a certain residue cover and corresponding erosion control benefit. This survey tests this assumption by noting residue levels on each field surveyed. It was also assumed that the same distribution of tillage and residue occurred along the road-side compared with fields away from the road-side.

4.3 Drawing a Sub-Sample from a Previous Study

An attempt was made to collect a representative sub-sample of the 1,115 survey sites conducted in the Cropping, Tillage and Land Management Practices study by Coleman and Roberts, March 1987. It was not possible to sample crop residue at all of these sites because they were not accessible from the road-side. However, several hundred fields from the previous study were accessible.

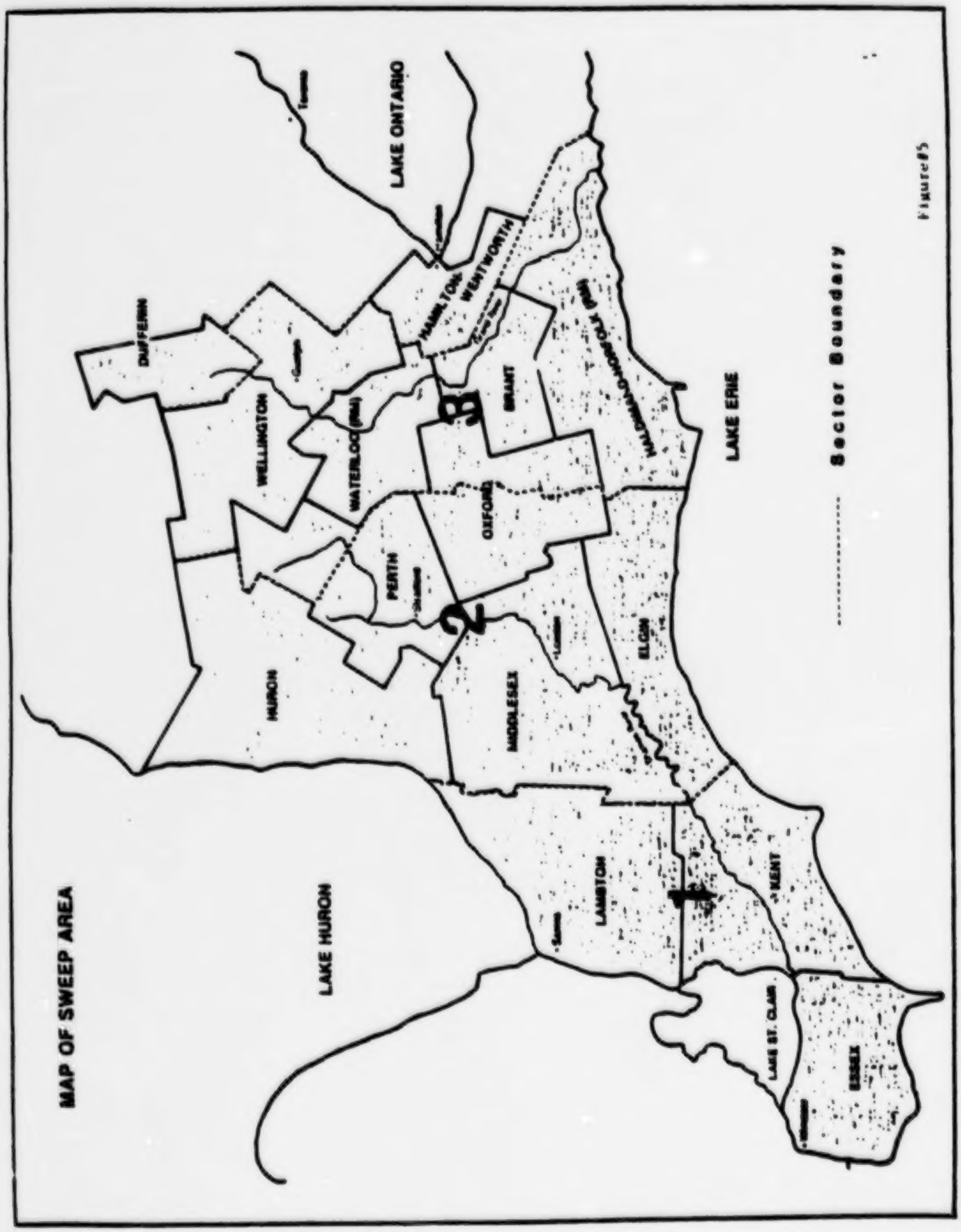
4.4 Preparations for Field Work

A one day workshop for the surveyors was held to review field procedures. The identification of tillage equipment, crops, and procedures for recording residue in terms of categories and actual measurements were reviewed through slide presentations and practical experience with an OMAF Soil Conservation Advisor. A field manual consisting of crop residue photos, record tally sheets, residue photos for general field procedures and accompanying residue recorder with instructions were taken to the field by each survey team.

4.5 Route Selection Considerations

Two trained people (driver and recorder) were required to recognize and measure residue cover, to identify tillage types and cropping patterns. A route was selected through each county. The routes selected were chosen by the Soil and Water Management Branch, OMAF in consultation with Environment Canada and Agriculture Canada. An attempt was made to cover most of the counties in the SWEEP study area (Figure 3). Knowing the level of residue at these farms is invaluable for determination of soil losses. Sample information was generally recorded at 0.8 kilometre (1/2 mile) intervals along the driving route.

To facilitate field procedures the study area was divided into 3 sectors (Figure 5). In sector 3, the four townships in Dufferin County and two townships in Hamilton-Wentworth were not visited. The dividing lines of the 3 sectors were established to accommodate the length of the driving routes, number of sample points (fields) required, and to reduce the travel time to and from the field by survey teams located in Chatham, London and Guelph.


MAP OF SWEEP AREA
LAKE HURON
LAKE ONTARIO
LAKE ERIE
DUFFERIN
WELLINGTON
WATERLOO (RM)
HAMILTON-WENTWORTH
BRANT
HALDIMAND-NORFOLK (RM)
OXFORD
PERTH
HURON
MIDDLESEX
ELGIN
LAMBTON
KENT
LAKE ST. CLAIR
ESSEX
1
2
3
Sector Boundary
Figure#5

Field staff were instructed to change routes or create additional routes only when road closures or unopened road allowances dictated so. Survey crews then sampled the new route, rejoining the pre-existing route as soon as possible.

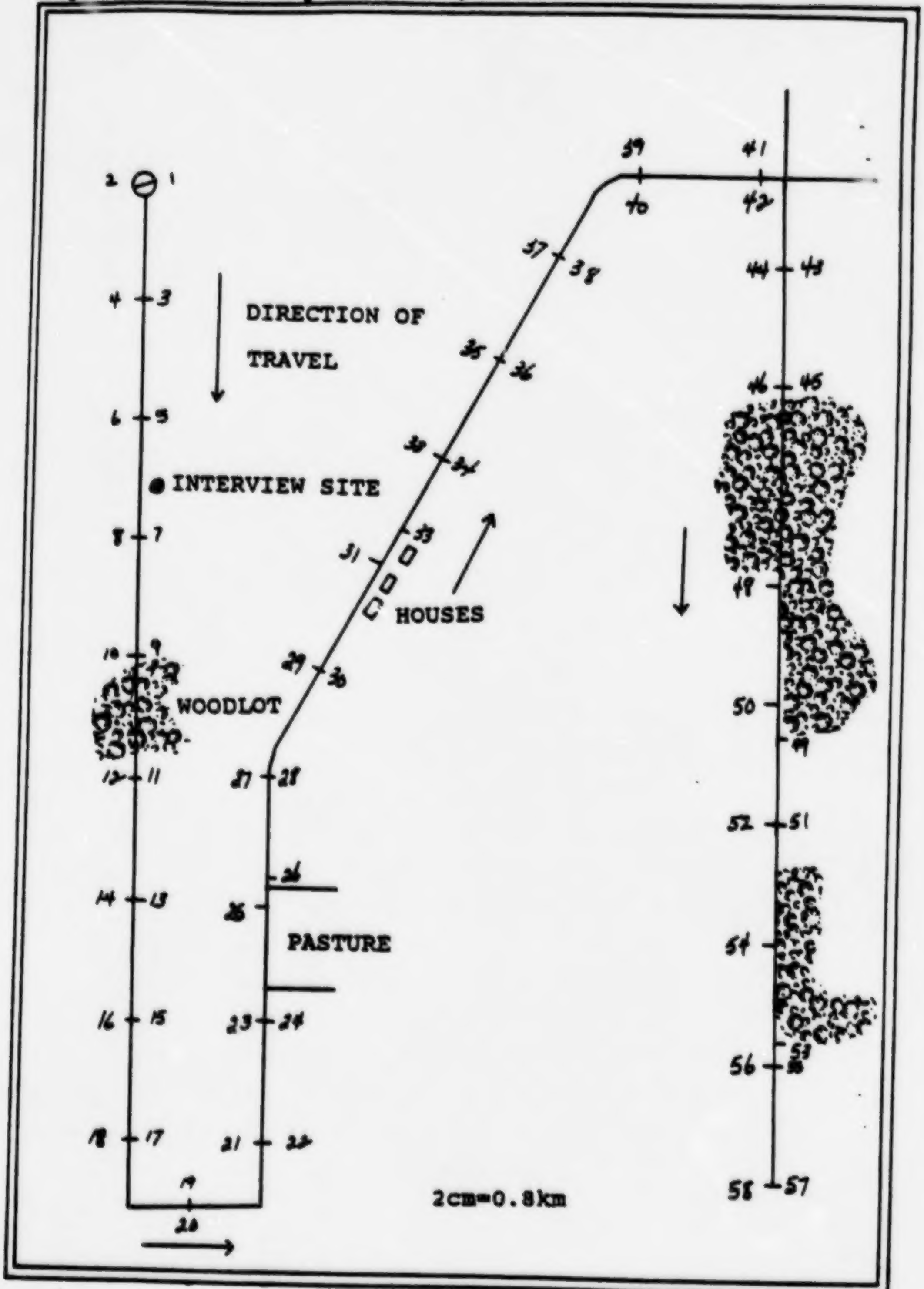
This procedure was necessary; otherwise, the number of sample points per county could not be achieved. Route alterations and additions were colour coded and identified on the county maps, and clearly indicated on the tally, summary and data sheets. Figure 6 illustrates an example of a possible driving route with numbered points and land use types.

Two important considerations were necessary in the selection of safe driving routes. It was important to plan driving routes off main roads to cover a higher proportion of cropland uses than those found along highways and regional roads, as well as to ensure the safety of the driver and recorder who made frequent stops. Adjustments to the 0.8 kilometre survey point location were made when a land use other than cropland (e.g. woodlot, pasture, housing, etc) existed at survey points on either the left or right hand side of the driving route. In these instances, the next cropped field was taken as the sample point.

Survey points were assigned a field number in a consecutive fashion. These were recorded on tally sheets (Appendix A) and located on county maps along the drawn route according to scale and with even numbers on the right hand side and odd on the left.

At these fixed field locations on each side of the road, crews (two people per vehicle - driver and recorder) estimated the percent residue cover, and recorded the previous crop planted, the present crop, and the tillage

Figure 6 Sample Driving Route



type. The tillage types recorded included conventional, reduced, ridge till and not tilled.

Residue cover percentages were taken using the knotted rope method. The rope is 3/16 inch diameter nylon, knotted with 50 knots each tied five inches apart. Every piece of residue touching a knot counts for 2% residue cover. The actual percentage residue was measured approximately every 20th field. At these locations, three residue measurements were recorded and averaged according to the rules outlined in Appendix C. The averaged reading determined the percentage residue category.

To increase precision, measurements of crop residue were taken every tenth field during the AST portion of the survey. Having the sample points with field numbers and mileage recorded on tally sheets, facilitated good preliminary analysis of the data.

At survey points, teams noted residue cover percentage, previous crops harvested or planted, present crops and estimated residue cover by category. Crop types recorded included corn, beans (soybeans, white and red and kidney beans), winter cereals or oil seeds, spring cereals or oilseeds, peas, hay/forage, other (tobacco, vegetables, roots and tubers), and land which was worked with no evident plant growth or with an unidentifiable crop.

Residue cover percentage category ranges of 0 - 15%, 15 - 30%, 30 - 45%, 45 - 75% and 75 - 100%, as well as tillage types, were selected based on work by Schaal (1986). Using these ranges improved relative accuracy. Conservation tillage practices enhance residue cover and provide erosion control benefit. Since the Soil and Water Environmental Enhancement Program (SWEEP) is interested in estimating the

relative soil losses from fields, it was very important to correlate tillage practices with a crop residue cover in the study area.

4.6 Analysis of the Data

The study consisted of roughly equal sets of survey data collected before and after secondary tilling had begun in the spring of 1987. The survey used the following classes to record present crops: 1) Corn, 2) Beans, 3) Spring Grain, 4) Fall Grain, 5) Hay/Forage, 6) Other (vegetables, tobacco,etc.), 7) Not Identifiable (Fallow).

When conducting analysis it became apparent that several crops recorded during the before secondary tillage portion of the study, had already received secondary tillage. In particular, fall grain crops had already received secondary tillage, as had hay/forage (sometime earlier). Consequently, fall grain and hay/forage were placed in the after secondary tillage category. The fields remaining in the before secondary tillage category were either untilled stubble or had been primary tilled. In either case, the present year crop had not been planted and thus could not be identified.

After reclassifying the fall grain and the forage/hay into the after secondary tillage category, approximately 2200 observations remained in the before secondary tillage (BST) category. Seventy nine hundred observations were then in the after secondary tillage (AST) category.

Having only one present crop category (unidentifiable) made comparison with the AST data difficult. To facilitate analysis, the data was pooled and treated as a single survey. The BST/AST aspect of the data was explored in a

limited number of tables. These are clearly indicated as being Before/After tables. All other tables refer to the entire set of data.

4.7 Limitations of the Study

A number of significant factors should be recognized in terms of the use of the survey methodology. Kush and Crawford, 1987, have concerns regarding the randomness of sampling along the roadside. They felt, but could not substantiate that the conservation fields, especially no-till fields, may occur in more remote locations on the farm, and on smaller fields because this practice is fairly new. Also conservation tilled fields have an unkept appearance when compared to fields tilled with a moldboard plough.

The impact of this factor on the present study was not assessed. However, as all types of reduced tillage gain wider acceptance, this problem should be eliminated. Therefore, statistically significant differences between the distribution of on-road versus off-road fields will be minimized with wider adoption.

Selection of the transect routes should be done to avoid roads that follow certain topographic features. Failure to do so could favour soil types; hence influence the reporting of tilling practices. The authors believe that the routes in this survey represented the most common features of the counties involved.

Field verification of residue categories by actual measurement is important in establishing the error associated with estimating residue cover. However, more frequent measurement requires a greater amount of time.

Time was very important to completion of the early part of the survey, since 1987 had an early planting season.

Accurate estimation of residue cover categories is imperative under varying field conditions. Good training workshops for survey personnel that involve many photographs of crop residue are beneficial in obtaining accurate survey results. In terms of estimating crop residue cover, it is imperative that field staff look at crop residue rather than percentage of soil cover to determine residue cover. The two measures are clearly related mathematically, but perceptually the two are not equivalent. Hence residue cover must be focussed upon explicitly.

The results of this survey apply to the SWEEP study area. Application of the data to either Central or Eastern Ontario should be made with caution.

5.0 FINDINGS

5.1 General Information Relating to Fields in the Study Area

Table 2 shows a county breakdown of the number of fields sampled in the study area. The actual number of fields sampled only fell short of that required by the multinomial distribution in Brant County.

Table 2 Fields Sampled in the Study Area

County	Number Of Fields	Percent Of Fields
Brant	362	4
Elgin	683	7
Essex	716	7
Haldimand-Norfolk	948	9
Huron	1140	11
Kent	983	10
Lambton	1131	11
Middlesex	1216	12
Oxford	666	7
Perth	879	9
Waterloo	518	5
Wellington	863	9
	----	----
Study Area	10105	100

Due to an early spring, accompanied by dry weather, many fields were worked earlier than usual. Survey teams commenced field work April 20, 1987. This was late for an early spring season. Driving routes were drawn to cover the majority of the SWEEP study area. Table 3 shows that six of twelve counties/regional municipalities had all townships surveyed. Those missed were either too inaccessible such as Pelee township, or had a lower agricultural capability. Examples of the latter are West Luther and Beverley townships which have large swamps.

Table 3 SWEEP Study Area Surveyed

County	Townships Not Surveyed
Wellington	West Luther
Haldimand-Norfolk	Houghton, Moulton, Oneida and Sherbrooke
Brant	+
Waterloo	Beverley
Perth	+
Oxford	+
Elgin	+
Kent	+
Essex	Pelee
Lambton	+
Middlesex	Delaware
Huron	Usborne and Ashfield

+ = townships all surveyed

5.2 Occurrence of Residue by County

Table 4 shows the frequency and percent occurrence of crop residue by County. A high proportion (84.5%) of study area fields occurred in the 0 - 15% category. It was shown in Figure 2 that residue levels above 30% effectively minimize soil loss. Table 4 shows that 7.2% of fields measured for residue met this criteria.

The Land Stewardship Program of OMAF is attempting to encourage 20% residue cover on farm fields. To determine how many fields already meet this criteria, an analysis of measured residue levels was conducted. This check revealed that 16% of fields have 20% or more residue cover.

Table 4 Residue Cover By County

County/Region	Percent Occurrence 0-15%	15-30%	30-45%	45-75%	75-100%
Brant	83.5	9.7	3.5	2.9	0.3
Elgin	75.6	11.6	8.4	4.0	0.3
Essex	76.0	12.4	5.5	5.8	0.3
Haldimand-Norfolk	78.4	13.7	3.9	3.7	0.4
Huron	88.7	5.3	5.1	0.7	0.1
Kent	74.0	15.8	5.9	3.3	1.1
Lambton	83.6	5.3	5.7	3.8	1.6
Middlesex	88.4	9.5	1.4	0.7	0.0
Oxford	89.7	5.2	2.5	2.5	0.1
Perth	89.8	6.1	2.7	1.2	0.1
Waterloo	88.8	3.7	4.8	2.2	0.5
Wellington	84.6	8.6	5.4	1.1	0.3
	----	----	----	----	----
Study Area	84.5	8.3	4.5	2.3	0.4

The highest frequency of occurrence in the 75 - 100% residue category was in Lambton (1.6%) and Kent (1.1%). Residue levels associated with reduced tillage (30 - 45%), occur most frequently in Elgin (8.4%) and Kent (5.9%). Having 85% of fields within the 0 - 15% residue category indicates that the widespread adoption of conservation practices has yet to occur.

Table 5 shows the percentage of fields surveyed which occur in each tillage category on a county basis during both the before secondary tillage phase and the after secondary tillage phase.
These results are illustrated graphically in Figure 7, Figure 8, Figure 9 and Figure 10.

Table 5 Tillage Category By County Before and After Secondary Tillage

County/Region	No. of Fields	Conventional	Reduced Tillage	Not Tilled	Ridge Tilled
		Before Secondary Tillage			
Brant	74	45.9	14.9	39.2	0.0
Elgin	242	67.4	9.5	20.2	2.9
Essex	300	69.7	12.3	16.0	2.0
Haldimand-Norfolk	178	42.1	50.0	7.9	0.0
Huron	102	63.7	5.9	25.5	4.9
Kent	424	93.6	1.2	2.4	2.8
Lambton	408	77.9	15.0	6.6	0.5
Middlesex	284	70.4	12.7	16.9	0.0
Oxford	105	31.4	18.1	50.5	0.0
Perth	45	57.8	8.9	33.3	0.0
Waterloo	22	40.9	18.2	40.9	0.0
Wellington	21	42.9	9.5	47.6	0.0
Study Area	2205	69.8	13.5	15.3	1.5

County/Region	No. of Fields	Conventional	Reduced Tillage	Not Tilled	Ridge Tilled
		After Secondary Tillage			
Brant	288	77.8	5.6	15.3	1.4
Elgin	441	85.9	2.9	10.9	0.2
Essex	416	93.0	2.6	4.1	0.2
Haldimand-Norfolk	770	62.2	24.9	12.7	0.1
Huron	1038	67.9	6.8	24.9	0.4
Kent	559	98.6	0.5	0.0	0.9
Lambton	723	98.3	0.8	0.0	0.8
Middlesex	932	84.1	1.8	14.1	0.0
Oxford	561	69.3	11.4	19.3	0.0
Perth	834	62.2	5.0	32.7	0.0
Waterloo	496	56.5	4.6	38.9	0.0
Wellington	842	48.7	6.7	44.7	0.0
Study Area	7900	73.6	6.5	19.6	0.3

Ridge tillage (Table 5) declined from 1.5% to 0.3% after planting. Perhaps the decline is due to the flattening of ridges during planting. Since the ridges are not re-formed until later in the season, ridges may be difficult to recognize shortly after planting.

During the after secondary tillage phase of the study, the majority of study area fields were classified as being conventionally tilled (73.6%), while 6.5% were reduced tilled, 19.6% were not tilled, and 0.3% were ridge tilled.

Figure 7 generally shows increases in the number of fields conventionally tilled during the AST phase whereas Figure 8 shows declines in the number of fields remaining untilled during the after secondary tillage phase. Both these figures reflect the predominant tilling practices. In part, the amount of change between the Before and after secondary tillage phases reflects large acreages which were unable to be tilled because of wet fall conditions. While these operating conditions are difficult for farmers, the consequence is a large amount of residue left until spring.

Figures 7 and 8 show that the counties of Brant and Oxford illustrate a high point spread between the BST phase and the AST phases of the survey for the conventional and not tilled categories respectively. In Figure 7, fields in conventional tillage during the BST phase have been primary tilled. In Figure 8, fields not tilled during the BST phase have over-wintered with stubble on the surface. Kent and Lambton have the highest percent of fields in conventional tillage before and after secondary tillage while Waterloo and Wellington had the lowest percent of fields in conventional tillage.

Figure 7 Percent Fields in Conventional Tillage

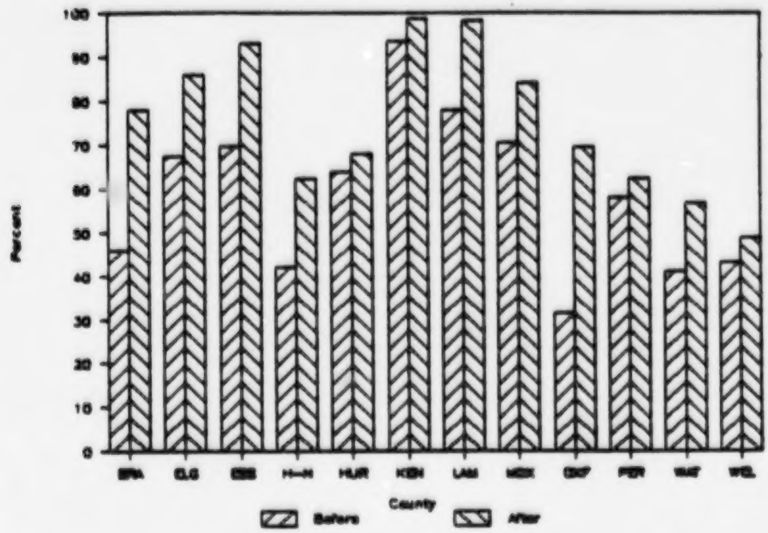


Figure 8 shows that for fields still not tilled during the AST phase, Wellington (44.7%) and Waterloo (38.9%) had the highest percentage figures while Kent (0%), Lambton (0%), and Essex (4.1%) were notably the lowest percent figures.

While conventional tillage remains at roughly the 70% level before and after secondary tillage (Table 5). Re[illegible]uced tillage, however, decreased by 50%. This may reflect residue losses associated with additional tillage during seedbed preparation.

The increase in the Not Tilled category, from 15% to 19% may correspond with increased forage production, increases in land left unworked for economic reasons or because the crops were planted using no-till techniques.

Figure 8 Percent Fields Not Tilled

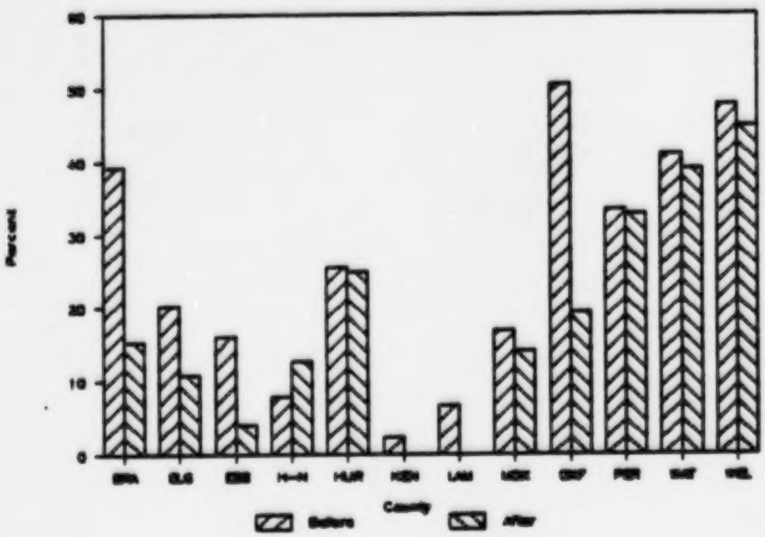
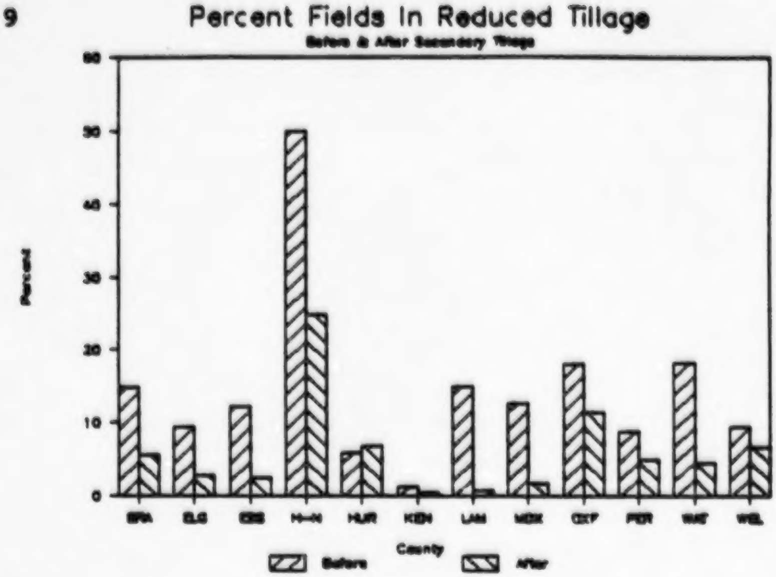


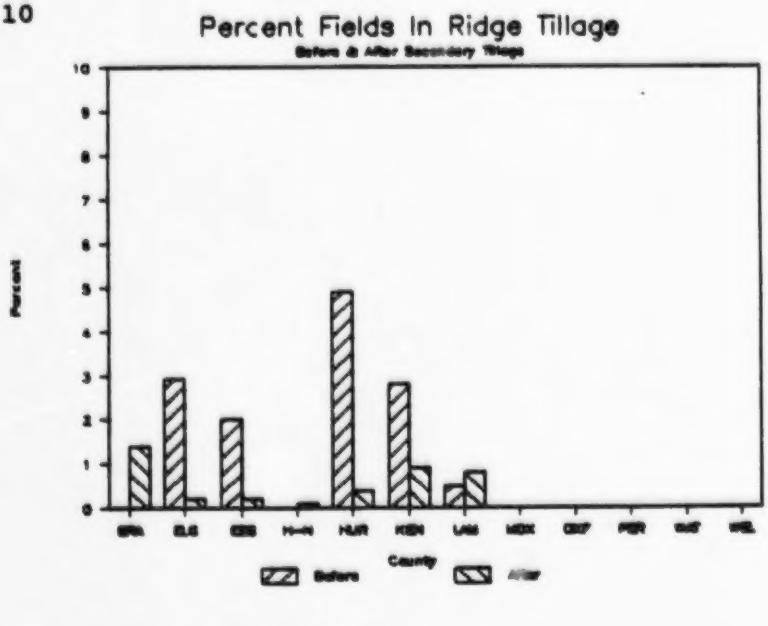
Figure 9 shows that the highest proportion in reduced tillage during the before secondary tillage phase occurred in Haldimand-Norfolk (50%) while the lowest proportion was in Kent (1.2%). Light soils in Haldimand-Norfolk's tobacco areas, which are often disced instead of ploughed, may be a reason for a high number of fields reduced tilled both before and after secondary tillage.

Figure 9



Fields in "ridge tillage" (Figure 10) were highest during the before secondary tillage phase in Huron (4.9%) and Kent (2.8%). Ridge tillage did not occur in many other counties. After secondary tillage, the highest percent of fields were found in Brant (1.4%) and Kent (0.9%).

Figure 10



5.2.1 Accuracy of Residue Estimation

Confidence in the residue data is important to reliability of interpretation results. A cross tabulation of actual measured residue category in percent by estimated residue cover category in percent shows the degree of confidence in the data in terms of each residue cover category. For all residue cover categories (Table 6) it can be said that for the 946 fields where actual residue measurements were taken, one can be over 96% confident that when a residue cover class was estimated, the value was in its proper class. Table 6 shows that the greatest degree of accuracy occurred for the 0 - 15% category while the confidence was still over 90% for the 15 - 30% and 45 - 75% ranges.

Table 6 Accuracy of Residue Cover Estimation

Residue Category	Number Correct	Total Fields	Percent Correctly Classified
0-15	706	725	97
15-30	99	108	92
30-45	59	62	95
45-75	41	45	91
75-100	6	6	100
All Classes	911	946	96

5.2.2 Residue Level by Tillage Type

Table 7 shows that the greatest number of study area fields had conventional tillage (72.8%), while 18.6% were not tilled, 8.0% of fields were reduced tilled, and 0.5% were ridge tilled.

The highest number of conventionally tilled fields (95.2%) occurred in the 0 - 15% residue category, while the lowest number was in the 75 - 100% residue category. For reduced tillage, the highest frequency occurred within the 15 - 30% residue category at 40.6%, with significant residue amounts (40.0%) in the 30 - 45% residue category.

In assessing the levels of residue in the ridge tilled and not tilled categories of 30-45%, 45-75% and 75-100% respectively, the higher residue levels found in Table 7 would be anticipated.

In Table 7, 7283 fields of 10105 (or 72.8%) occur in the 0 - 15% residue category. Most of these fields appear to be in conventional tillage. The 75-100% residue category is dominated by entries in the not-tilled category. Most of this category is made up of forage and hay crops. These are densely growing crops which tend to provide a high degree of surface cover.

Table 7 Residue Level By Tillage Type

Residue Level Percent	Number of Fields	Percent Occurrence Conventional %	Reduced %	Ridge Till %	Not Tilled %
0-15	7283	95.2	3.6	0.3	0.9
15-30	739	44.4	40.6	0.3	14.7
30-45	445	9.7	40.0	4.0	46.3
45-75	235	3.0	6.9	3.0	69.6
75-100	39	3.3	1.2	0.1	95.3
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Study Area	10105	7356	811	54	1884
Percent	100.0	72.8	8.0	0.5	18.6

5.3 Present Crop by County After Secondary Tillage

Table 8 shows that fields with corn (26.3%) were the most predominant. Hay or forage constituted 20.9%, while spring and fall grain made up 11.9% and 12.5% respectively. The high proportion of land appearing fallow may be due to the fact that at the time of the survey, the crops in many fields had not yet germinated sufficiently to be recognized. This especially seems to be the case in Kent County.

Table 8 Present Crops by County After Secondary Tillage

	Percent Occurrence						
County/Region	Corn %	Beans %	Fall Cereals %	Spring Cereals %	Hay or Forage %	Other %	Fallow %
Brant	23.6	1.7	11.1	10.8	19.8	5.2	27.8
Elgin	37.4	20.2	14.1	3.9	12.0	7.0	5.4
Essex	20.7	32.5	8.2	3.4	4.3	7.5	23.6
Hald.-Norfolk	17.9	8.2	22.3	12.3	16.1	13.9	9.2
Huron	29.6	2.5	9.9	18.3	24.7	0.2	14.8
Kent	20.2	4.8	9.7	0.2	0.2	0.0	64.9
Lambton	23.8	29.6	21.3	8.3	0.1	0.1	16.7
Middlesex	33.3	3.6	16.2	8.7	14.6	1.0	22.6
Oxford	45.3	2.9	9.6	8.6	21.7	2.1	9.8
Perth	20.7	5.6	12.2	20.0	33.3	0.2	7.8
Waterloo	16.9	0.0	7.9	19.6	44.0	0.4	11.3
Wellington	25.1	3.7	3.8	16.5	46.0	1.0	4.0
Study Area	26.3	8.7	12.5	11.9	20.9	2.8	16.9

5.4 Frequency of Occurrence of Crop Residue by County

Table 9 shows that fields with corn residue (34.9%) were the most predominant. Approximately 18% of the fields had bean residue, while small grains residue was found in 18.9% of the fields. Hay or forage residue made up 16.6% of the residue found.

Table 9 Crop Residue Type By County After Secondary Tillage

	Percent Occurrence					
County/Region	Corn	Beans	Small Grains	Hay or Forage	Other	Not Identifiable
Brant	40.9	15.2	17.7	18.2	0.8	7.2
Elgin	48.6	18.6	17.0	4.2	2.5	9.1
Essex	22.8	32.4	25.7	3.5	2.8	12.8
Hald.-Norfolk	25.0	11.7	26.2	13.9	12.2	11.0
Huron	33.9	2.6	22.2	19.9	0.6	20.7
Kent	42.2	35.7	16.4	0.1	0.0	5.6
Lambton	29.6	50.2	15.6	1.5	0.1	3.0
Middlesex	45.6	18.2	19.2	8.9	0.0	8.1
Oxford	54.8	4.1	15.6	18.2	0.2	7.2
Perth	24.1	1.5	18.1	30.7	0.1	25.5
Waterloo	30.7	6.6	15.6	45.0	0.0	2.1
Wellington	25.7	1.9	15.5	52.4	0.1	4.4
Study Area	34.9	17.7	18.9	16.6	1.7	10.2

Other fields at (1.7%) consisted of vegetable, tubers, roots and tobacco crops. Fallow fields at 10.2% had been worked and the crop was not yet identifiable. Their highest occurrence was in Perth at 25.5%.

Oxford county had the highest proportion of corn fields at 54.8% while Essex at 22.8% was the lowest. The occurrence of bean fields was highest in Lambton at 50.2% and lowest was in Perth at 1.5%. Fall grains were most predominant in Haldimand-Norfolk 26.2% and Essex 25.7% and lowest in Wellington at 15.5%.

Figure 11 Forage and Hay - 1986 versus 1987

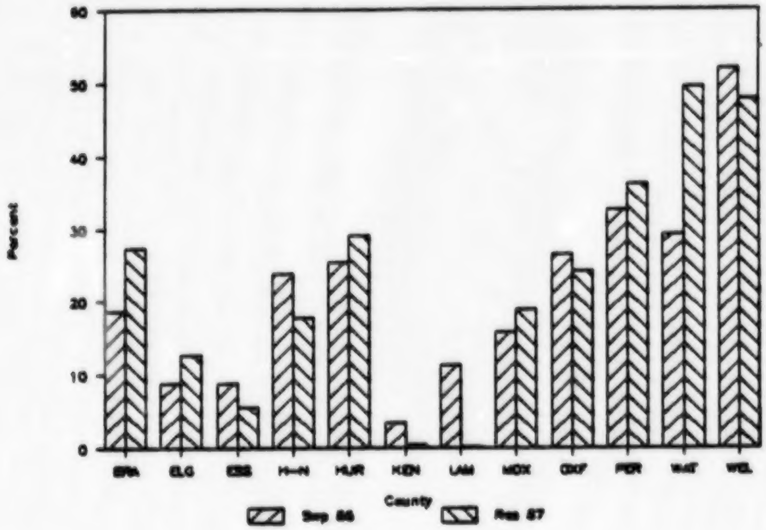


Figure 12 Spring Cereals 1986 versus 1987

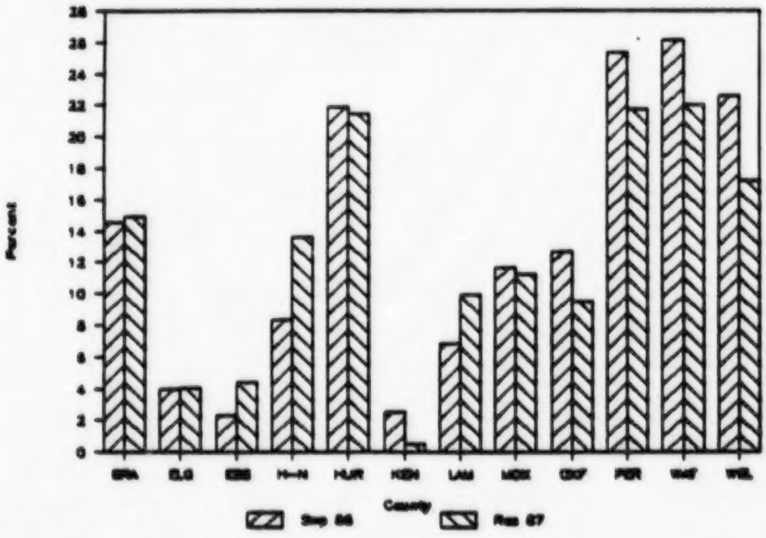


Figure 13 Fall Cereals 1986 versus 1987

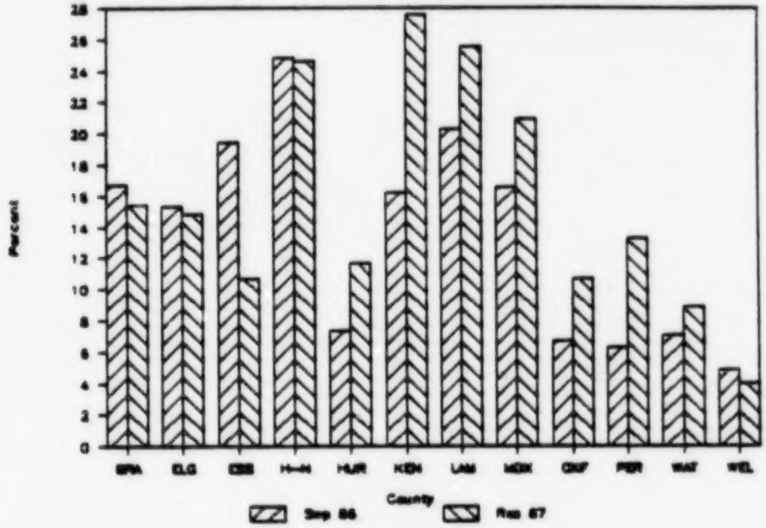


Figure 14 Fruit, Vegetables 1986 versus 1987

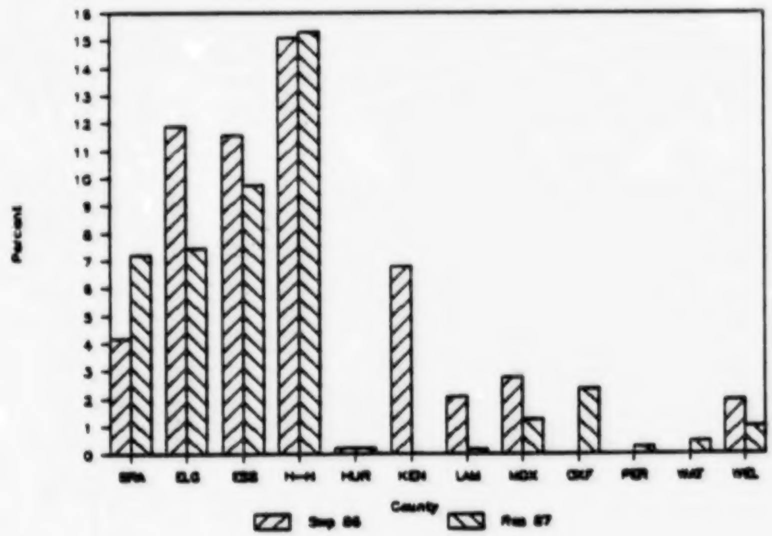


Figure 15 Corn Crops 1986 versus 1987

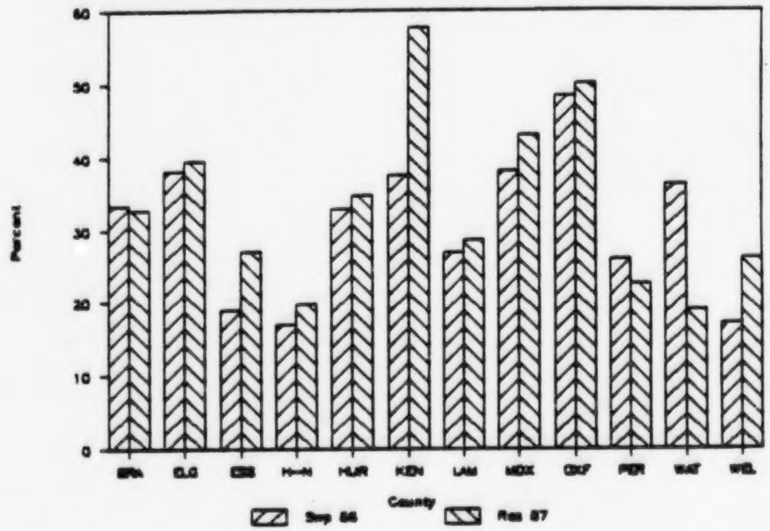
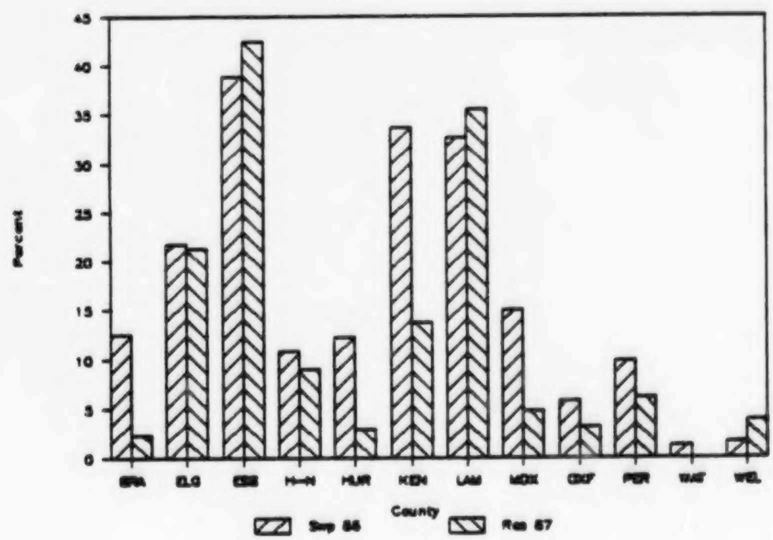


Figure 16 Bean Crops 1986 versus 1987



5.5 Cropping Sequences in the Study Area

One of the more interesting pieces of information available from the survey has to do with cropping sequence. Table 10 gives the probability of finding various crops following a given previous crop. For example, where the present crop was corn, 63.4% of those fields had previously been corn, 16.6% of corn crops had previously been small grains, 11.1% of fields had previously been seeded to beans. Four percent of fields had insufficient residue to determine what the previous crop had been. Using a similar approach, one can derive the proportions of any crop following a given crop from the table.

Table 10 Probabilities for Cropping Sequences

	Percentage Occurrence Previous Crop						
	Corn %	Beans %	Small Grain %	Forage %	Other %	Not Ident. %	Row Total %
Present Crop							
Corn	63.4	11.1	16.6	4.2	0.1	4.4	26.3
Beans	30.4	38.9	19.7	2.0	0.3	8.7	8.7
Fall Cereals	9.1	19.8	26.6	1.3	10.8	32.4	12.5
Spring Cereal	30.1	8.4	29.1	4.1	0.3	27.9	11.9
Forage	1.0	0.6	13.8	83.3	0.2	1.1	20.9
Other	4.5	6.8	20.5	10.5	14.1	43.6	2.8
Not Ident.	42.6	20.1	22.4	7.1	0.6	7.3	16.9
Total	31.6	13.5	20.1	20.8	2.0	12.0	100.0

5.6 Residue Levels Associated with Previous Crops

Table 11 shows levels of residue for previous crops before and after secondary tillage. The destruction of residue occurs with each successive pass of tillage equipment. Levels of residue that were not identifiable during the BST phase were very low (3.8%) but increased to 12% during the AST phase.

After secondary tillage, higher proportions of fields occurred in the 0 - 15% residue cover category. Most losses occurred in the 45 - 75% and 75 - 100% residue category. A wet fall season results in an unusual amount of spring tillage. However, reduced fall tillage allows for greater over-winter soil cover and mitigates erosion.

Table 11 Crop Residue Levels Before and After Secondary Tillage

Before Secondary Tillage

		Crop Residue					
Residue Cover Percent	No. of Fields	Corn %	Beans %	Small Grains %	Forage %	Vege-tables %	Not Indent-ifiable %
0-15	1531	70.4	61.4	80.2	54.3	40.0	94.0
15-30	275	10.2	19.8	5.9	5.7	20.0	6.0
30-45	223	9.2	12.8	7.7	20.0	40.0	0.0
45-75	150	8.8	5.0	5.2	17.1	0.0	0.0
75-100	26	1.5	1.0	0.9	2.9	0.0	0.0
Fields	2205	1034	718	324	35	10	84
Percent	100.0	46.9	32.6	14.7	1.6	0.5	3.8

After Secondary Tillage

		Crop Residue					
Residue Cover Percent	No. of Fields	Corn %	Beans %	Small Grains %	Forage %	Other %	Not Indent-ifiable %
0-15	5752	83.3	95.6	83.5	14.5	94.3	99.5
15-30	464	12.1	3.2	6.1	1.3	3.2	0.3
30-45	222	3.1	0.6	7.9	0.4	2.5	0.2
45-75	80	1.4	0.7	2.1	0.2	0.0	0.0
75-100	1382	0.1	0.0	0.3	83.5	0.0	0.0
Fields	7900	2496	1067	1589	1646	157	945
Percent	100.0	31.6	13.5	20.1	20.8	2.0	12.0

The proportion of fields in corn having just 0 - 15% residue cover increased from 70.4% during the BST phase to 83.3% during the AST phase. By comparison, the higher corn residue categories lost a total of approximately 16% of fields.

The proportion of fields in beans having 0 - 15% residue increased from 61.4% during the BST phase to 95.6% during the AST phase. The higher bean residue categories lost a total of approximately 17% of the fields.

Corresponding losses in residue which occurred for the remaining crops are indicated in Table 11.

During the BST phase, 54.3% of forage fields occurred in the 0 - 15% residue category. These were fields which had been plowed down in preparation for planting another crop. Hay which remained in the after secondary tillage portion of the study was being kept an additional year. As a consequence, this type of residue appears in the 75-100% residue category.

5.7 Residue Levels for Cropping Sequences

This section of the report gives the probability of finding certain residue levels in a given crop following any previous crops. Tables 12 - 18 give the residue levels associated with present crops of corn, beans, fall and spring grains, forage/hay, vegetables, and fallow land.

In the following tables, the terminology used to describe cereals depends on whether a present crop or previous crop residue is the subject of discussion. Present crops of cereals are classified into Spring or Fall Grain. Previous crop residue for cereals occurs under the Small

Grain category, since planting season can no longer be distinguished.

Each of the above tables will show the distribution of crop residue by residue category for a present crop-previous crop residue combination. For example, for corn following corn, 79.8% of the fields occurred in the 0 - 15% residue category, 14.4% of the fields had 15 - 30% residue, 4.2% of the fields had 30 - 45% residue; 1.5% of the fields had 45 - 75% residue and 0.1% of corn fields had 75 - 100% residue cover.

These distributions can be used to assess the probability of having a certain level of residue for a given previous - present crop combination. By combining several previous - present crop combinations, one can estimate the probability of finding a given level of crop residue through the cropping sequence.

Tables 12 to 18 also give the mean value of residue cover for any present crop - previous crop combination. These values represent the amount of residue that has been found on average for crops in the study.

Residue levels in a cropping sequence can be derived from the information from Tables 15 to 18.

Table 12 Crop Residue Levels in Corn After Secondary Tillage

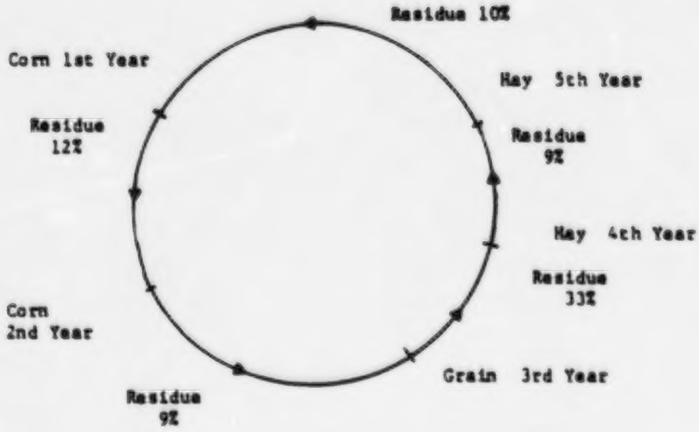
Residue Cover Percent	No. of Fields	Previous Crop Residue Percent Occurrence Corn %	Beans %	Small Grains %	Forage %	Vege-tables %	Not Ident-ifiable %
0-15	1800	79.8	99.6	98.0	92.0	100.0	100.0
15-30	201	14.4	0.4	1.4	5.7	0.0	0.0
30-45	57	4.2	0	0.6	0.0	0.0	0.0
45-75	22	1.5	0	0.0	2.3	0.0	0.0
75-100	1	0.1	0	0.0	0.0	0.0	0.0
Fields	2081	1320	232	346	88	3	92
Percent	100.0	63.4	11.1	16.6	4.2	0.1	4.4
Mean %		12	8	8	10	8	8

As an illustration, the average residue associated with some common cropping rotations will be demonstrated. For example, in a rotation involving corn - corn - grain - hay-hay (Figure 17), in the first year, the present crop is corn with previous crop residue of hay/forage (Table 12).

Here, 10% crop residue would be expected. In the second year when corn follows corn, one would expect to find an average of 12% residue cover (Table 12).

In the third year of the rotation, the present crop is spring grain which is planted into corn residue. From this, an average residue cover of 9% would be expected (Table 13).

Figure 17 Cropping Sequence 1



Average Residue over Rotation 27%

Table 13 Crop Residue Levels in Spring Cereals After Secondary Tillage

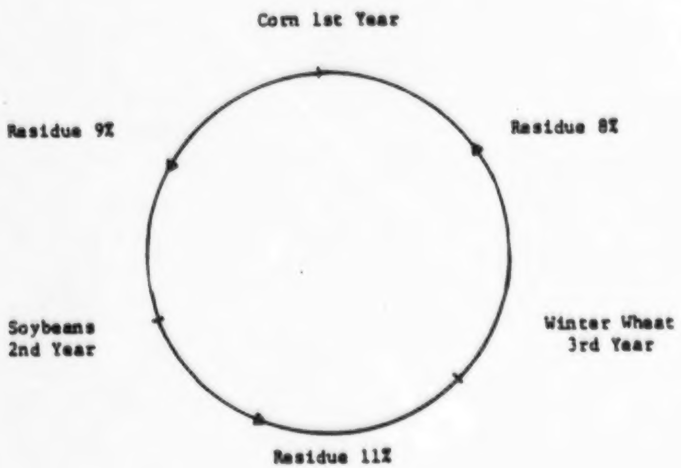
Residue Cover Percent	No. of Fields	Previous Crop Residue Percent Occurrence: Corn %	Beans %	Small Grains %	Forage %	Vege-tables %	Not Indent-ifiable %
0-15	894	90.8	98.7	95.3	89.7	33.3	100
15-30	42	8.1	1.3	4.4	10.3	66.7	0
30-45	2	0.4	0	0.4	0	0	0
45-75	2	0.7	0	0	0	0	0
75-100	0	0	0	0	0	0	0
Fields	940	283	79	274	39	3	262
Percent	100.0	30.1	8.4	29.1	4.1	0.3	27.9
Mean %		9	8	8	9	18	8

Hay follows small grain in the fourth year of the rotation, and a crop residue cover of 33% would be anticipated (Table 14). In the final year of the rotation when hay follows hay, an average residue cover of 73% would result. Over the rotation, the average value of crop residue was 27%.

Table 14 Crop Residue Levels in Forage/Hay After Secondary Tillage

Residue Cover Percent	No. of Fields	Corn %	Beans %	Small Grains %	Forage %	Vegetables %	Not Indentifiable %
		Previous Crop Residue Percent Occurrence					
0-15	85	11.8	7.1	56.5	0.0	3.5	21.2
15-30	41	4.9	2.4	92.7	0.0	0.0	0.0
30-45	108	1.9	0.9	97.2	0.0	0.0	0.0
45-75	37	8.1	5.4	86.5	0.0	0.0	0.0
75-100	1380	0.0	0.0	0.4	99.6	0.0	0.0
Fields	1651	17	10	228	1375	3	18
Percent	100.0	1.0	0.6	13.8	83.3	0.2	1.1
Mean %		22	23	33	73	8	8

Figure 18 Cropping Sequence 2



Average Residue over Rotation 9%

Similarly, for a rotation involving corn, beans and winter wheat (Figure 18), expected crop residues can be derived. During the first year, the present crop is corn and the previous crop residue is from a small grain. An average residue cover of 8% (Table 12) can be expected. In the second year, 9% residue cover can be expected for a bean crop following corn (Table 15). In the third year, fall grain follows beans. Here, 11% crop residue cover (Table 16) would be anticipated. Over the rotation, the average value of crop residue was 9%.

Table 15 Crop Residue in Beans After Secondary Tillage

		Previous Crop Residue Percent Occurrence					
Residue Cover Percent	No. of Fields	Corn %	Beans %	Small Grains %	Forage %	Vege-tables %	Not Indent-ifiable %
0-15	664	93.3	99.6	96.3	78.6	100	100
15-30	17	5.3	0.4	3.7	0	0	0
30-45	6	1.4	0	0	21.4	0	0
45-75	0	0	0	0	0	0	0
75-100	0	0	0	0	0	0	0
Fields	687	210	267	135	14	2	60
Percent	100	30.5	38.9	19.7	1.9	0.3	8.7
Mean %		9	8	8	14	8	8

From the two preceding illustrations, the increase in crop residue cover which results from incorporating a forage into the rotation can be seen. The same procedure can be applied to assess the expected residue from other crop rotations. Table 17 and Table 18 have been included for this purpose.

Table 16 Crop Residue Levels in Fall Grains After Secondary Tillage

Residue Cover Percent	No. of Fields	Previous Crop Residue Percent Occurrence: Corn %	Beans %	Small Grains %	Forage %	Vege-tables %	Not Ident-ifiable %
0-15	889	86.7	83.7	82.1	69.2	100.0	98.4
15-30	68	11.1	11.7	11.0	23.1	0.0	0.9
30-45	26	2.2	2.6	6.1	7.7	0.0	0.7
45-75	6	0.0	2.0	0.8	0.0	0.0	0.0
75-100	0	0.0	0.0	0.0	0.0	0.0	0.0
Fields	989	90	196	263	13	107	320
Percent	100.0	9.1	19.8	26.6	1.3	10.8	32.4
Mean %		10	11	11	13	8	8

Residue levels for previous crops after secondary tillage, where the present crops is Vegetables, are shown in Table 17.

Table 17 Crop Residue Levels in Vegetables After Secondary Tillage

Residue Cover Percent	No. of Fields	Previous Crop Residue Percent Occurrence: Corn %	Beans %	Small Grains %	Forage %	Vege-tables %	Not Indent-ifiable %
0-15	208	80.0	93.3	93.3	100.0	80.6	100.0
15-30	7	10.0	6.7	6.7	0.0	6.5	0.0
30-45	4	0.0	0.0	0.0	0.0	12.9	0.0
45-75	1	10.0	0.0	0.0	0.0	0.0	0.0
75-100	0	0.0	0.0	0.0	0.0	0.0	0.0
Fields	220	10	15	45	23	31	96
Percent	100.0	4.5	6.8	20.5	10.5	14.1	43.6
Mean %		14	9	9	8	12	8

Residue levels in fields classified as fallow, that is worked but not identifiable, are shown in Table 18.

Table 18 Crop Residue Levels on Fallow Land

Residue Cover Percent	No. of Fields	Previous Crop Residue Percent Occurrence					
		Corn %	Beans %	Small Grains %	Forage %	Vege-tables %	Not Indent-ifiable %
0-15	1212	84.0	97.4	97.7	85.1	87.5	100.0
15-30	88	11.6	2.2	1.7	10.6	12.5	0.0
30-45	19	2.6	0.0	0.7	2.1	0.0	0.0
45-75	12	1.6	0.4	0.0	2.1	0.0	0.0
75-100	1	0.2	0.0	0.0	0.0	0.0	0.0
Fields	1332	567	268	298	94	8	97
Percent	100.0	42.6	20.1	22.4	7.1	0.6	7.3
Mean %		11	8	8	11	9	8

6.0 CONSIDERATIONS FOR FUTURE WORK

6.1 Resurvey of Crop Residues

It is recommended that the survey be repeated before the final year of the SWEEP agreement to provide information regarding changes in tillage practices and residue cover levels. This survey has provided confirmation of the results of the Cropping and Tillage and Land Management Practices survey (Coleman and Roberts 1987). Expected residue levels are difficult to deduce from interview data; however the interviews indicate that the dominant forms of tillage correlate strongly with the observed levels of crop residue found in the field survey. A second survey of crop residues in fields in conjunction with the second set of interviews in 1989 would confirm the adoption of conservation practices.

6.2 Analysis of Crop Residues for Personal Interview Sites

During the crop residue survey a sub-sample of 234 farms included in the interview survey of 1986 were assessed for crop residue. For these sites, an analysis of residue levels in relation to cropping and tillage practices should be made. The greater detail of cropping and tillage information should provide useful insights into the observed levels of crop residue.

6.3 Operational Considerations for Future Crop Residue Surveys

The survey was designed to be a before and after survey of crop residues. The before data turned out to be useful in a limited fashion. During the before secondary tillage (BST) portion of the study the only crops apparent were untilled crop stubble, primary tilled fields, forage/hay fields and fall planted grain. Even during this BST phase,

the fall grain and the forage have already received secondary tillage and hence should be considered a crop which was being viewed after secondary tillage. From this viewpoint, the only before secondary tillage fields are those which have not been tilled and those which have received primary tillage.

The main value of the BST portion is to allow estimation of the amount of over-winter erosion protection afforded by a forage/hay and fall planted grain crops.

In the AST survey, timing proved to be a critical factor. If the survey is conducted too close to planting, difficulty in identifying the planted crop arises. This is due to the fact that the crop has not had sufficient time to germinate and grow.

If the survey is not completed within six weeks of planting time, then field crews begin to have difficult in identifying previous crop residues, and obtaining reliable measures due to the height of the crop.

Thought should be given to how existing hay fields should be treated in terms of crop residue. In second year (or older) hay, residue from the previous crop may not occur in substantial amounts. However, the standing crop could be considered the "residue" from the previous year. In this case "residue" levels will fall in the 75 - 100% category. This latter approach was adopted in this analysis.

7.0 SUMMARY

This report has presented the results of a survey of crop residue occurring in over 10,000 fields in the Sweep study area. The data were collected by field staff in the spring of 1987. The survey gathered data on crop residue cover for various combinations of crops and tillage systems. County and Regional summaries of the data were produced.

Analysis of the data shows that the greatest number of study area fields had conventional tillage (73%). While 19% of the fields were untilled, 8% showed reduced tillage, and less than 0.5% were ridge tilled.

Over 94% of the fields in the conventional category had 0 - 15% crop residue cover. For reduced tillage, crop residue most frequently occurred in the 15-30% category, with a significant number of occurrences in the 30 - 45% residue category.

The report details the probability of finding crop residue within one of five categories for any given present crop category. Weighted average percent residue cover is calculated for each previous crop. These tables provide a means to assess the average crop residue from cropping sequences.

The report provides information on the current state of crop residue in the SWEEP study area, and provides a number of points of comparison for subsequent studies of the adoption of conservation practices.

8.0 BIBLIOGRAPHY

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APPENDIX A **Reference Guide for Tally Sheet**

County: ________________ Date: ________ Completed by: ____________

Approximate starting point: township/town/village or route followed: ________

Mileage	Twn/RN	Field #	B/A	Residue Cover %	Present Crops	Previous Crops	Tillage Type	Actual %
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....
				1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7	1 2 3 4	....

Tally Sheet Codes

Residue Cover %

1. 0-15%
2. 15-30%
3. 30-45%
4. 45-75%
5. 75-100%

Tillage Type

1. Conventional
2. Reduced
3. Not tilled
4. Ridge tillage

Present Crops

1. Corn
2. Beans
3. Winter Cereals or Oilseeds
4. Spring Cereals or Oilseeds
5. Hay/Forage
6. Other (Tobacco, Vegetable, Roots, Tubers)
7. Fallow (worked with no evident plant or worked with unidentifiable crop)

Previous Crop

1. Corn
2. Beans (White, Soy., Kidney, Coloured, Peas)
3. Small Grains (Cereals, Oilseeds, Other than Soys)
4. Forage/Hay
5. Other (Vegetable, Tubers, Roots, Tobacco)
6. Not identifiable

APPENDIX B DEFINITION OF TILLAGE SYSTEMS

Note: The following definitions are based on the current (1987) public understanding and use of the terms.

Conventional Tillage (Moldboard Plough)

The tillage system which disturbs the total soil surface by cutting, inverting and shattering the soil almost totally incorporating crop residues learning less than 20% of the soil surface covered with residue after planting.

Reduced Tillage (minimum tillage, mulch tillage, strip tillage)

The tillage system that includes some form of tillage generally based on the use of a chisel plough, disc/coulter chisel plough, heavy disc harrow or moldboard plough (spring only) in the fall and/or spring. Crop residues are partially incorporated learning a minimum of 20% of the soil surface covered with residue after planting.

Ridge Tillage

A system of tillage where a ridge of soil is formed after harvest or when cultivation for weed control in the crop is done. The next crop is planted directly into the ridge top, which is usually 4-6 inches higher than the row middles. The old crop row is scalped off and the new crop is planted into the prepared seedbed. Crop residues are partially incorporated into the soil during ridge formation and/or cultivation. A minimum of 20% of the soil surface is covered with residue through the year. (This may vary depending on timing of ridge formation and previous crop residue type). Cultivation is used to rebuild ridges. Weed control is accomplished with a combination of herbicides and cultivation.

No Tillage (no-till, zero tillage, slot plant, non-powered strip tillage, modified no-till)

This tillage system leaves the soil undisturbed prior to planting. Planting is done in a narrow seedbed with either a drill type planter where rows are 6-10 inches apart or a row crop type planter where rows are generally 28-40 inches apart (some at 15 inches). Best results are achieved with drill type planters designed for heavy residue

conditions. Weed control is accomplished primarily with herbicides. At least 30% of the soil surface is covered by crop residue after planting.

These definitions are based on usage found in the following three sources which are cited fully in the bibliography.

Sources:

D.M. Kush and E.B. Crawford, 1987.

R.A. Thompson, 1986.

D. Young and C.S. Baldwin, 1986.

APPENDIX C ESTIMATING RESIDUE COVER

Measuring Residue Cover with the Residue Recorder

Conservation tillage includes a wide variety of tillage and planting systems that leave at least 30% of the previous crop's residue on the soil surface after planting to protect against soil erosion. Crop residue shields the soil surface by intercepting the pounding force of raindrops and by slowing the rate of runoff. This helps to prevent soil movement by allowing more time for water to infiltrate the soil. An easy and reliable method to measure residue cover is with the RESIDUE RECORDER.

Directions:

The reliability of the knotted-rope method is maximized by always following these procedures:

1. Anchor the stake and stretch the knotted rope diagonally (45 degrees) across the crop rows.

2. Do not measure in headlands or "turn round" areas.

3. Do not measure parallel to a tillage operation.

4. Standing over the rope and looking straight down, count the number of knots that touch crop residue. Do not count stones or weeds and ignore pieces of residue smaller than 1/8" x 1-1/4" as they are considered too small to intercept a raindrop. Take all readings on the same side of the rope.

5. Multiply the number of knots that touch residue by 2 to estimate the percentage residue cover. Repeat the process at least 3 times at randomly selected sites in the field and average the results.

REMEMBER: the amount of residue remaining is affected by:

- the choice of machinery and the speed and depth at which it is operated
- the soil type and moisture content, and,
- the type and condition of the crop

Source: Joint Agricultural Soil and Water Conservation Program Upper Thames River, Kettle Creek and Catfish Creek Conservation Authorities and the Ontario Ministry of Agriculture and Food, London, Ontario